

PENGARUH BAHAN ORGANIK DAN KALSIUM TERHADAP STRUKTUR MIKRO TANAH

Soil Microstructure As Affected by Organic Matter and Calcium

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ABSTRACT

Soil microstructure as affected by organic matter and calcium was investigated by polarising microscope examination after three months incubation and by scanning electron microscopy (SEM) after one month incubation. Both polarising microscopy and SEM observations revealed an improvement of soil microstructure with the addition of cow dung and wheat straw. Compared to the addition of dung, the straw amendment resulted in a greater microorganism diversity and larger porosity values.

Keywords: Soil microstructure, Cow dung, wheat straw, calcium, polarising microscopy, scanning electron microscopy (SEM)

INTRODUCTION

Soil structure at the microscopic scale can be described by examination of the soil pore and matrix relationships (micromorphology). Such methods as soil thin section examination (Bullock *et al.*, 1985; Kodesova *et al.*, 2006) using polarising light microscope and scanning electron microscopy (SEM) (Tisdall & Oades, 1982; Metzger & Robert, 1985; Chenu, 1993) are useful tools that have been widely used to examine the complexity of organic matter and soil particle relationship within micro aggregates. The use of SEM in many studies of soil microstructure have confirmed the correctness of a model of a soil crumb (Figure 1) proposed by Emerson (1954). The model showed clay domains linked with quartz particles due to the presence of organic material which in the form of organic polymers strengthen the binding between the quartz and clay domains by linking the quartz surface and the edge or basal surfaces of the clay.

Dutartre *et al.*, (1993) observed that soil aggregate stability was mainly controlled by organic matter in the fine fraction (<20 μm) of soil. Decomposed organic matter had a strong association with clay minerals, forming organo-mineral micro aggregates (plasma) and cementing sands into larger structural units. Soil particles adhered to organic material improves the micro aggregates of the soil, which eventually increases aggregate stability (Pagliai & Antisari, 1993).

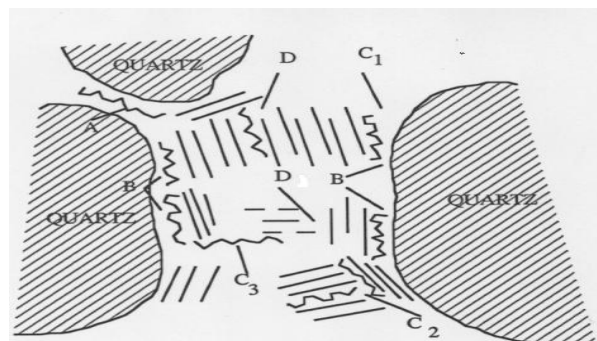


Figure 1. A Model Of A Soil Crumb Due To The Present Of Organic Matter (Emerson, 1954). (D = Clay Domains; C = Organic Polymers)

Sullivan and Koppi (1987) used scanning electron microscopy to examine the distribution of organic material located on, or near, structural surfaces. They found electron-translucent organic matter coatings up to 0.5 mm thick and electron-opaque organic matter coatings on structural surfaces within the soil.

Scanning electron microscopy was also used by Metzger and Robert (1985) to observe the effects of sludge addition on the microaggregation of soil. They found that the organic components of the sludge coated the clay particles and bound the soil particles together promoting aggregation and caused the formation of microaggregates. They suggested that different components such as polysaccharides, polypeptides, and humic acids were responsible for bridge formation between clay particles, as well as coating and envelopment of the clay particles by organic substances.

Chenu (1989) studied the influence of a fungal polysaccharide, scleroglucan, on clay microstructures. He found that the most striking feature of the scleroglucan complexes is the presence of abundant scleroglucan fibres which are 0.2-1 mm in length and about 0.01 mm in diameter and appear to be linked to the clay surfaces by their extremities. The microorganization of the scleroglucan fibres has been associated with various polysaccharides (Chenu, 1993). The results suggested that the adsorption of the scleroglucan leads to the formation of an organo-mineral network, in which the arrangement of mineral particles is mostly unchanged. A Study of the role of roots, fungi and bacteria on clay particle organisation by Dorioz *et al.* (1993) confirmed the above result. They found that with fungi, three main effects were observed: (i) orientation of clay particles around the cells, (ii) secretion of extracellular polysaccharides that induced local binding of clay particles, and (iii) a general packing

effect by hyphae. These effects led to a new microstructure, in the immediate surroundings of the cell, designated as a microenvironment.

Straw and other crop residues added to soil can be used to improve aggregate stability as they provide a substrate for microorganisms to produce stabilising agents Gilmour *et al.* (1948). Different organic materials added to the soil can give a range of different effects on soil aggregation. Carbonaceous materials such as oat straw, wheat straw, rye, buckwheat, corn stover and peat moss, which are known to be resistant to decomposition, result in soils with fewer large size aggregates than soils receiving materials with a higher content of nitrogen such as alfalfa and soybean (Browning & Milan, 1944). Soil aggregate stability also can be improved by adding animal waste. However, relatively few studies have been aimed at quantifying this (Lynch & Bragg, 1985).

Weill *et al.* (1988) found that the application of dairy manure to soil significantly increased the relative amount of >250 μm aggregates by 20 % compared to soil in which no dairy manure was applied. The organic matter contained in these aggregates was the most highly correlated to the formation of the 2 to 4.75 mm aggregates. They also found that most of the organic matter was associated with the 5 to 20 μm fraction.

This project aims to describe the effect of organic materials and calcium on soil microstructure with the specific objectives was to examine the physical relationships of various organic materials and calcium with soil microstructure.

MATERIALS AND METHODS

Soil Sampling Procedures

The soil was collected from the cultivated layer (top 15 cm) of paddock D2 of The Lincoln University Research Farm. The

soil was a Templeton silt loam over sand (Cox, 1967) and the site had been used for two years of vegetable production (potatoes and cabbages) following after pasture. The soil was air dried and sieved to obtain aggregates between 2-4 mm diameters.

Dung and Straw Sampling Procedures

Fresh cow dung was collected from the pasture surface at the Lincoln University Dairy Farm and crushed to pass through a 4 mm sieve. Straw material, consisting of the whole tops of the threshed residue of mature wheat plants, was ground by machine to pass through a 2 mm mesh.

Polarising Microscopy Investigation

To describe the soil microstructure using the polarising microscope, thin sections of soils were made by impregnating soil with epoxy resin (Fitzpatrick, 1984). This was done after three months incubation. Eight incubation treatments (Table 1) were selected on the basis of the aggregate stability results (Hasanah, 2005).

Table 1. The Main Treatments For Polarising Microscopy Investigation

Treatment	Rate (t/ha)
Control	0
Dung	25
Dung	50
Straw	25
Straw	50
Gypsum	10
Calcite	7.36
Dung+Straw	50 each

Duplicate cores (45 mm diameter), as a modification of Kubiena tins, were taken from each treatment by gently pushing the cores into the soil surface. The cores were carefully cut away from the surface and

excess soil trimmed off before the cores were placed in plastic containers. Water was removed from the cores by the acetone replacement technique (Murphy, 1986). The cores were saturated with acetone and left for a week. The displaced water and excess acetone were removed using a suction pump. Fresh acetone was then added and the process was repeated over a 6 week period until no water was present within the acetone. The cores were then drained and impregnated with polyester resin.

Once the blocks were sufficiently hard, the outer containers and any remnants were removed. The blocks were then ground and polished on a lapping machine (Logitech, Scotland). The polished surface was mounted onto a glass microscope slide. A thin section of 25-30 μm thickness was obtained with further cutting and polishing (Fitzpatrick, 1984; Kemp, 1985; Murphy *et al.*, 1985; Hammond, 1989; Kodesova *et al.*, 2006). The thin section was then mounted with a cover slip.

Scanning Electron Microscopy Investigation

Scanning electron microscopy (SEM) (Plate 4.1) was used to observe soil from four treatments: namely the control soil, the cow dung treatment at the equivalent of 25 t/ha, the straw treatment at the equivalent of 25 t/ha, and the dung plus straw treatment at the equivalent of 25 t/ha each. The observations were carried out in a wet-state using a cryostage on a Leica S440 scanning electron microscope (Cambridge, UK).

A wet soil sample was attached to an aluminium stub with an acrylic cement and frozen at -146°C by immersion into liquid nitrogen. The stub was then placed in a sample chamber attached to the SEM at -40°C . The soil surfaces were superficially lyophilised and coated with gold to provide a conductive film. Samples were observed at a

temperature less than -110°C in the refrigerated column of a Leica S440 scanning electron microscope. The presence of organic matter and microorganisms such as bacteria and fungi were evaluated for all treatments (Heijnen *et al.*, 1993; Dorioz *et al.*, 1993).

RESULTS AND DISCUSSION

The use of the polarising microscope in conjunction with scanning electron microscopy (SEM) allowed observation of the soil microstructure at two different scales. The polarising microscope provided information concerning soil pores and the distribution of the organic matter component, while SEM gave valuable information concerning microorganism interactions with the soil matrix.

Polarising Microscopy Observations

Using the polarising microscope, it could be seen that soil porosity was increased following the addition of either dung or straw or dung plus straw. This indicated that the soil microstructure had been improved. Straw addition tended to produce larger stable aggregates than dung addition. This

result suggests that addition of both dung and straw improves soil porosity which in turn improves aeration, and is likely to lead to improved moisture retention, infiltration and hence microbiological activity and plant growth as well as reducing the risk of soil erosion. All these characteristics are very important for sustainable agriculture.

On the other hand, calcium addition resulted in degradation of soil microstructure as evidenced by a very compact soil. This observation confirmed the aggregate stability measurements in which calcium tended to decrease soil aggregate stability.

Control treatment

In the control treatment (Plate 1a,b), the microstructure tends to be blocky to granular with channel and chamber voids predominant (from $<50\text{ }\mu\text{m}$ - $500\text{ }\mu\text{m}$ to 2 mm). Vughs are also commonly found in this treatment ($< 200\text{ }\mu\text{m}$). Most of the organic matter in this treatment was associated with the micromass. There was no obvious coarse organic matter fraction. The micromass of the Templeton soil can be identified by its light brown colour in plane polarised light

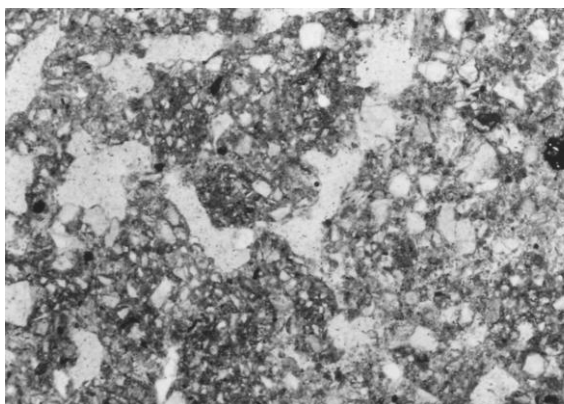


Plate 1a. Control treatment (plane polarised light, width of photo = 2.5 mm)

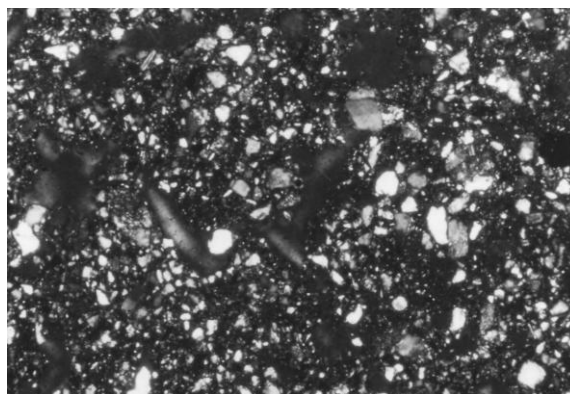


Plate 1b. Control treatment (cross polarised light, width of photo = 2.5 mm)

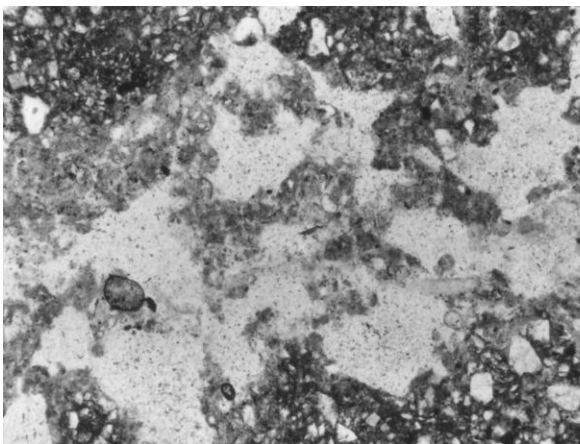


Plate 2a. Effect Of Dung Addition (Equivalent To 25 t/ha) On Soil Microstructure (width of photo = 2.5 mm)

Dung treatment

Both dung treatments show a more granular microstructure when compared to the control treatment (Plates 2 a,b). As in the control treatment, channel and chamber voids predominated, however, the void sizes were larger (100 μm - >500 μm .). Vughs also occurred as did a few circular voids (100 - 200 μm) with a characteristic circular ring of groundmass. The dung was recognisable as granular nodules (100 - 200 μm) with a yellow brown colour in plane polarised light.

The dung could also be recognised as composed of plant fragments, which could also be seen in SEM observations (Plate 2b). The dung was found both infilling voids, where it appeared as a porous crumb microstructure, or intimately mixed with the Templeton soil groundmass.

The appearance of the dung at the rate of 25 t/ha (Plate 2a) was similar to the higher rate (50 t/ha) (Plate b). However, both the mixed dung-soil groundmass and the crumb microstructure were more evident at the higher rate. The dung accounted for 10% of the coarse organic component at the low rate and 20% at the higher rate.

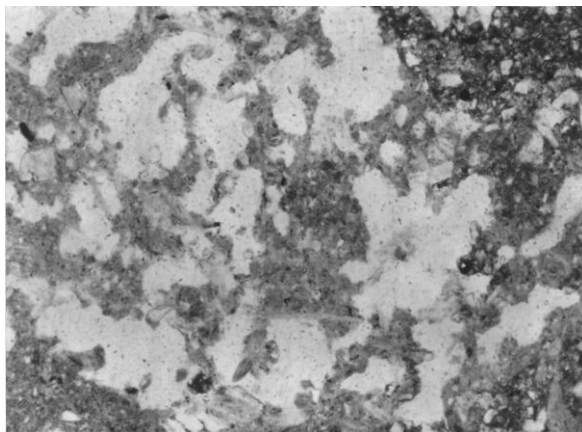


Plate 2b. Effect Of Dung Addition (equivalent to 50 t/ha) on Soil Microstructure (width of photo = 2.5 mm)

Straw treatment

The effect of 25 t/ha and 50 t/ha of straw on soil microstructure is shown in Plates 3a and 3b, respectively. The predominant voids in the wheat treatments were channels and chambers, but compared to the dung treatment, there are few vugh voids at the low treatment level. Most of the voids are >200 μm .

The straw fragments are easily recognisable by their cellular structure, yellow-brown colour and weak birefringence in cross-polarised light. Fragments were found incorporated into aggregates, and also within voids where they appeared to link aggregates together. This resulted in a granular microstructure. The abundance of this type of organic matter was as high as 30% when the straw was added at the highest rate of 50 t/ha. At the 50 t/ha of straw treatment (Plate 3b), there were more vughs and a stronger granular to crumb microstructure compared to the 25 t/ha straw treatment (Plate 3a). The presence of the straw organic component at the higher treatment level was easily recognisable.

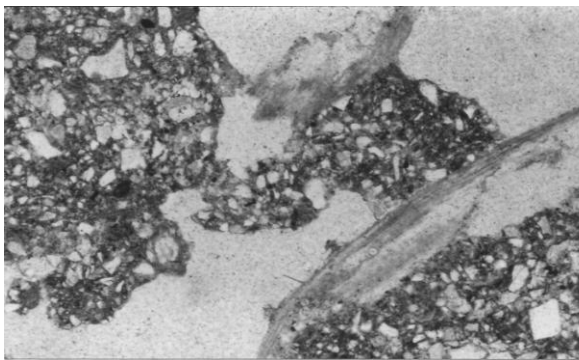


Plate 5.3a. Effect of straw addition (equivalent to 25 t/ha) on soil microstructure (width of photo = 2.5 mm)

Calcium treatment

Both the gypsum (Plate 4a) and calcite treatments (Plate 4b) showed the presence of vugh voids $<100\ \mu\text{m}$, with void size decreasing in the gypsum treatment. The microstructure was massive, when compared to the control treatment. There were few channels or chambers in either treatment. There was no obvious organic component associated with the groundmass compared to the dung or straw treatments.

Dung plus straw treatment

In this treatment (Plate 5a,b), both the organic components of the dung and straw were clearly visible. It appeared that

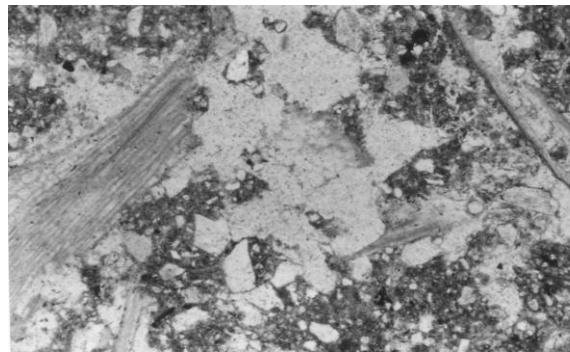


Plate 5.3b. Effect of straw addition (equivalent to 50 t/ha) on soil microstructure (width of photo = 2.5 mm)

this treatment resulted in the greatest improvement in soil microstructure. Most of the voids were chambers and channels, predominantly $>300\ \mu\text{m}$. Aggregates were connected together by straw fragments, either bridging between aggregates, or incorporated into the aggregates. The dung formed zones with crumb microstructure, intimately mixed with both mineral soil material and straw fragments. Several small circular voids ($100 - 200\ \mu\text{m}$) (with a characteristic circular ring of groundmass) were present, similar to that found in the lowest dung treatment. The regularity of shape suggests that these may be of a burrowing faunal origin.

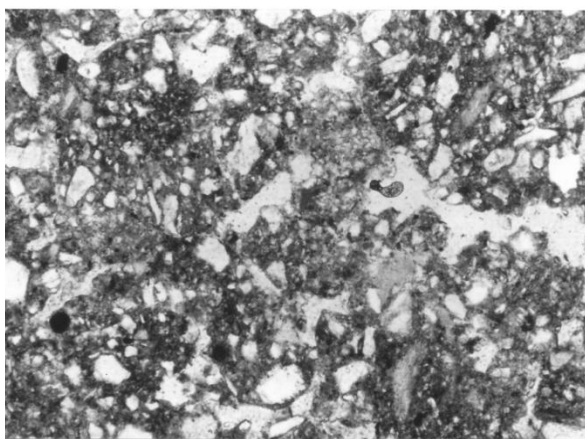


Plate 4a. Effect of calcite addition on soil microstructure (width of photo = 2.5mm)

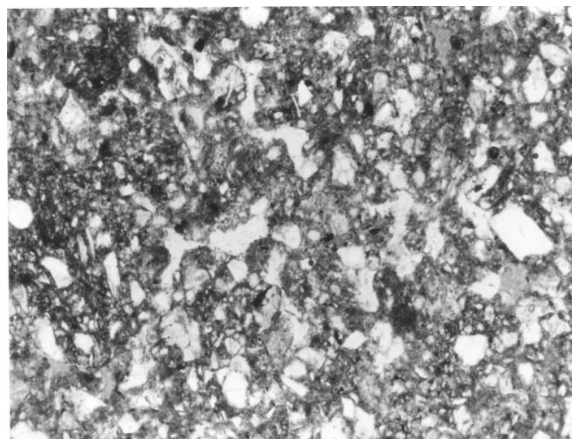


Plate 4b. Effect Of Gypsum Addition On Soil Microstructure (width of photo = 2.5 mm)

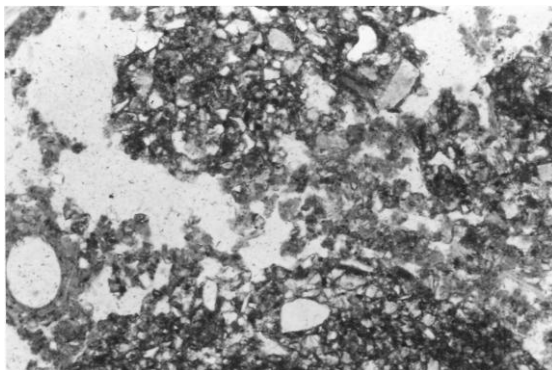


Plate 5a. Effect of dung plus straw addition on soil microstructure (width of photo = 2.5 mm)

Scanning Electron Microscopy Observations

Scanning electron microscopy observations clearly demonstrated the importance of dung and straw addition as a source of energy for microorganism activity particularly fungi which then produced gum or mucilages, which bind the soil particles together and produce high soil aggregate stability.

Control treatment

There was no distinct organic matter in the control soil, either in large

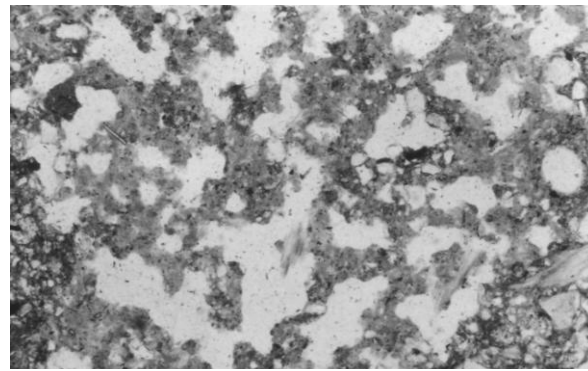


Plate 5b. Effect of dung plus straw addition on soil microstructure (width of photo = 2.5 mm)

macroaggregates ($>250\ \mu\text{m}$) or in small microaggregates ($<250\ \mu\text{m}$) (Plates 6a,b).

Dung treatment

At the scale of SEM observations, the dung treatment showed that organic materials were coated and mixed with inorganic soil particles (Plate 7a). A more detailed examination of this feature (Plate 7b) revealed an extensive network of fungal hyphae with soil particles firmly attached to them. Dung materials formed small microaggregates ($90 - 250\ \mu\text{m}$) composed of plant fragments.

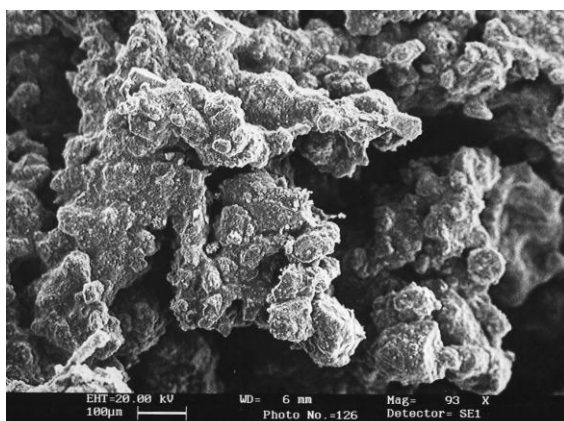


Plate 6a. Control soil (SEM image at 93x magnification)

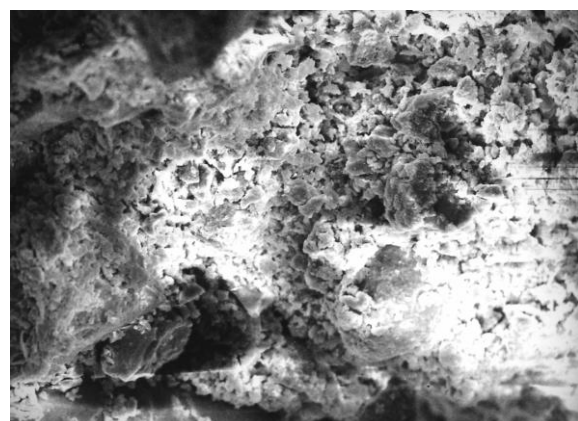


Plate 6b. Control soil (SEM image at 414x magnification)



Plate 7a. Effect Of Dung On Soil crostructure (SEM image at 89x magnification)



Plate 7b. Effect Of Dung On Soil Microstructure (SEM image at 924x magnification)

These SEM observations of improved microstructure are supported by the aggregate stability results in which dung applied at a low rate (equivalent to 25 t/ha) significantly increased the mean weight diameter (MWD) (Hasanah, 2005).

Straw Treatment

Investigation by SEM showed the effect on soil microaggregates following straw addition (Plate 8a). The straw fragments were found to be completely encrusted with inorganic soil particles. At high magnification (Plate 5.8b), it was found that the surface of the straw fragment had a network of fine fungal hyphae. This result

agrees with Allison and Killham (1988) who reported that soil microorganisms were increasingly fungal due to straw addition. They also showed that straw incorporation caused a proliferation of cellulose-decomposing fungi.

Lynch and Bragg (1985) considered the role of fungi as both aggregate forming and aggregate stabilising. Fungal hyphae form a network that bind soil particles together and force their contact with binding agents such as extracellular polysaccharides and mucilages (Chenu, 1989; Dorioz et al., 1993).

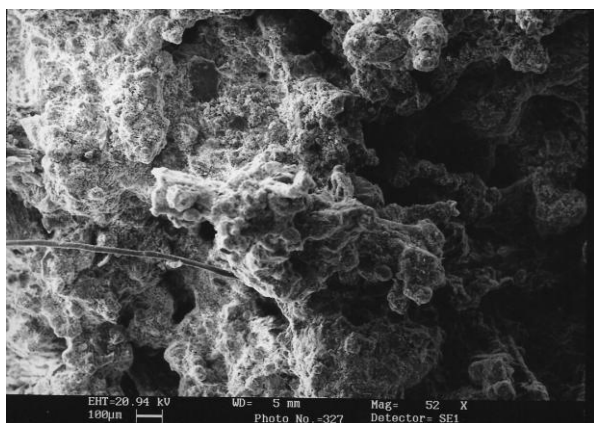


Plate 8a. Effect of straw on soil microstructure (SEM image at 52x magnification)

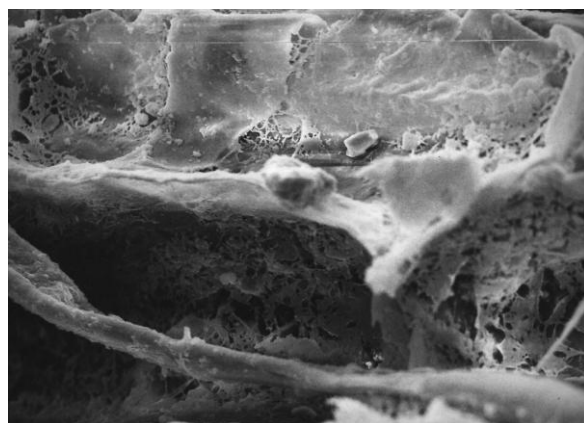


Plate 8b. Effect of straw on soil icrostructure (SEM image at 969x magnification)

The appearance of the straw fragments was obviously different from dung material. Straw fragments tended to exist in a single fragment with larger microaggregates (>250 μm). This straw effect may be similar to the effect of root system and VA mycorrhizal hyphae which also stabilise soil macroaggregates >250 μm (Tisdall and Oades, 1979). Again these SEM observations of improved microstructure agree with the results of the effect of straw on aggregate stability in which 25 t/ha of straw significantly increased the MWD (Hasanah, 2005).

CONCLUSION

Polarising microscope and SEM observation revealed: (a) improved soil microstructure of dung and straw- treated soil, with the addition of dung resulting in smaller stable aggregates than the addition of straw, (b) degraded soil structure under calcium treated soil.

The use of polarising microscope in conjunction with scanning electron microscopy (SEM) to observe the soil microstructure proved to be very useful since the polarising microscope provided information about soil pores and organic matter component, while SEM provided information about soil microorganisms which form stable aggregates.

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